transmission of 3·0 km. per sec. The agreement of this with the observed rate of transmission of the sensible shock is held to indicate that both are due to a form of wave motion which was propagated at a uniform rate along the surface of the earth. The first two phases, it is suggested, are due to wave motion transmitted through the interior of the earth, and as in the presumably isotropic, or nearly so, material of the interior of the earth a separation of condensational and distortional waves could take place, which Knott and Rudzki have shown to be impossible in the rocks of which the surface of the earth is composed, it is suggested that these two phases are due to the arrival of the condensational and distortional waves respectively, travelling by brachisto-chronic paths through the interior of the earth.

This suggestion is followed up in the second paper. The published records of distant earthquakes were looked up, and those selected of which the time and place of origin were known within a limit of error of 1 minute of time and 1 minute of arc respectively. Further, on account of the known impossibility of separation of the two simple forms of elastic wave motion in the surface crust of the earth, only those records were considered which came from a distance of not less than 20° of arc from the epicentre.

Seven distinct earthquakes were found of which the published records satisfied all these conditions, and as in some of them there was more than one shock, they constituted eleven distinct shocks. From the published records were extracted (1) the time of commencement of the record; (2) the time of any sudden increase of movement, when recorded; and (3) the time of maximum displacement. Tabulating these, it is found that each earthquake exhibits a three-phase character in the record; and, further, that if the times are plotted and a curve drawn through them, the time curves of the first two phases show precisely that curvature which Prof. Rudzki's investigations show to be characteristic of wave motion propagated along brachisto-chronic paths through the earth, where the rate of propagation increases with the depth. Continuing these curves by extrapolation to the origin, they give rates of propagation fairly concordant with the rates of propagation of condensational and distortional waves as experimentally determined for ordinary rock. As a subsidiary part of this investigation, it is shown that the "preliminary tremors" of earthquakes coming from Japan to Europe reach a depth of about ·45 of the radius from the surface, attain there a maximum velocity of 14·5 km. per sec. for the condensational, and 8·8 km. per sec. for the distortional wave, and traverse a medium which has, at that point, a bulk modulus of 17 times, and a rigidity of about 21·5 times that of granite.

The records of the third phase show some irregularity, but the time curve is a straight line, pointing to a uniform rate of transmission along the surface. There is, however, some indication that in the case of the greatest earthquakes it is higher than in the case of lesser ones; in other words, that the rate of transmission is in some way dependent on the magnitude of the earthquake, hence, probably, on the size of the wave. From this it is concluded that the propagation of these surface undulations is, in part at least, gravitational.

EXPLORATIONS OF THE "ALBATROSS" IN THE PACIFIC.[1]

WE left San Francisco in August of last year, and in latitude 31° 10′ N., and longitude 125° W., we made our first sounding in 1955 fathoms, about 320 miles from Point Conception, the nearest land. We occupied 26 stations until we reached the northern edge of the plateau from which rise the Marquesas Islands, having run from station No. 1, a distance of 3800 miles, in a straight line.

At station No. 2 the depth had increased to 2368 fathoms, the nearest land, Guadeloupe Island, being about 450 miles, and Point Conception nearly 500 miles, distant. The depth gradually increased to 2628, 2740, 2810, 2881, 3003 and 3088 fathoms, the last in lat. 16° 38′ N., long. 130° 14′ W., the deepest sounding we obtained thus far in the unexplored part of the Pacific through which we were passing. From that point the depths varied from 2883 to 2690 and 2776, diminishing to 2583, and gradually passing to 2440, 2463 and 2475 fathoms until off the Marquesas, in lat. 7° 58′ S., long. 139° 08′ W., the depth became 2287 fathoms. It then passed to 1929, 1802 and 1040 fathoms in lat. 8° 41′ S., long. 139° 46′ W., Nukuhiva Island being about 20 miles distant. Between Nukuhiva and Houa-Houna (Ua-Huka) Islands we obtained 830 fathoms, and 5 miles south of Nukuhiva 687 fathoms. When leaving Nukuhiva for the Paumotus we sounded in 1284 fathoms about 9 miles south of that island. These soundings seem to show that this part of the Marquesas rises from a plateau having a depth of 2000 fathoms and about 50 miles in width, as at station No. 29 we sounded in 1932 fathoms.

Between the Marquesas and the north-western extremity of the Paumotus we occupied nine stations, the greatest depth on that line being at station No. 31, in lat. 12° 20′ S., and long. 144° 15′ W. The depths varied between 2451 and 2527 fathoms, and diminished to 1208 fathoms off the west end of Ahii, and then to 706 fathoms when about 16 miles N.E. of Avatoru Pass in Rairoa Island.

Between Makatea and Tahiti we made eight soundings, beginning with 1363 fathoms, 2 miles off the southern end of Makatea, passing to 2238, 2363 (the greatest depth on that line), to 2224, 1930, 1585, 775, and finally 867 fathoms off Point Venus.

The deep basin developed by our soundings between lat. 24° 30′ N., and lat. 6° 25′ S., varying in depth from nearly 3100 fathoms to a little less than 2500 fathoms, is probably the western extension of a deep basin indicated by two soundings on the charts, to the eastward of our line, in longitudes 125° and 120° W., and latitudes 9° and 11° N., one of over 3100 fathoms, the other of more than 2550 fathoms, showing this part of the Pacific to be of considerable depth and to form a uniformly deep basin of great extent, continuing westward probably, judging from the soundings, for a long distance.

I would propose, in accordance with the practice adopted for naming such well-defined basins of the ocean, that this large depression of the Central Pacific, extending for nearly thirty degrees of latitude, be named Moser Basin.

The character of the bottom of this basin is most interesting. The haul of the trawl made at station No. 2, lat. 28° 23′ N., long. 126° 57′ W., brought up the bag full of red clay and manganese nodules with sharks' teeth and cetacean ear-bones; and at nearly all our stations we had indications of manganese nodules. At station No. 13, in 2690 fathoms, lat. 9° 57′ N., long. 137° 47′ W., we again obtained a fine trawl haul of manganese nodules and red clay; there must have been at least enough to fill a 40-gallon barrel.

The nodules of our first haul were either slabs from 6 to 18 inches in length and 4 to 6 inches in thickness, or small nodules ranging in size from that of a walnut to a lentil or less; while those brought up at station No. 13 consisted mainly of nodules looking like mammillated cannon-balls varying from 4½ to 6 inches in diameter, the largest being 6½ inches. We again brought up manganese nodules at the equator in about longitude 138° W., and subsequently—until within sight of Tahiti—we occasionally got manganese nodules.

As had been noticed by Sir John Murray in the *Challenger*, these manganese nodules occur in a part of the Pacific most distant from continental areas. Our experience has been similar to that of the *Challenger*, only I am inclined to think that these nodules range over a far greater area of the Central Pacific than had been supposed, and that this peculiar manganese-nodule bottom characterises a great portion of the deep parts of the Central Pacific where it cannot be affected by the deposits of globigerina, pteropods, or telluric ooze; in the region characterised also by red-clay deposits. For in the track of the great equatorial currents there occur deposits of globigerina ooze in over 2400 fathoms for a distance of over 300 miles in latitude.

We made a few hauls of the trawl on our way, but owing to the great distance we had to steam between San Francisco and the Marquesas (3800 miles) we could not, of course, spend much time either in trawling or in making tows at intermediate depths. Still the hauls we made with the trawl were most interesting, and confirmed what other deep-sea expeditions have realised: that at great depths, at considerable distances from land, and away from any great oceanic current, there is comparatively little animal life to be found.

The bottom temperatures of the deep (Moser) basin varied between 34·6° at 2628 and 2740 fathoms, to 35·2° at 2440

[1] Abridged from letters written to the Hon. George M. Bowers, U.S. Commissioner of Fish and Fisheries, Washington, D.C., by Mr. Alexander Agassiz, leader of the expedition of the U.S. Fish Commission Steamer *Albatross* to the Pacific.

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fathoms, and 35° at 2475 fathoms; about 120 miles from the Marquesas.

Our deep-sea nets not having reached San Francisco at the time we sailed, we limited our pelagic work to surface hauls, of which we generally made one in the morning and one in the evening, and whenever practicable some hauls with the open tow nets at depths varying between 100 and 350 fathoms. The results of these hauls were very satisfactory. The collection of surface animals is quite extensive, and many interesting forms were obtained. As regards the deeper hauls with the Tanner net, they only confirm what has been my experience on former expeditions, that beyond 300 to 350 fathoms very little animal life is found, and in the belt above 300 fathoms a great number of many so-called deep-sea crustaceans and deep-sea fishes were obtained. I may mention that we obtained Pelagothuria at about 100 fathoms from the surface.

On our way to Tahiti from the Marquesas we stopped a few days to examine the westernmost atolls of the Paumotus. Striking Ahii we made for Rairoa, the largest atoll of the Paumotu group. Skirting the northern shore from a point a little west of Tiputa Pass. we entered the lagoon through Avatoru Pass, anchoring off the village.

We made an examination of the northern side of the lagoon between Avatoru and Tiputa Passes. The lagoon beach of the northern shore is quite steep, and is composed of moderately coarse broken coral sand at the base, and of larger fragments of corals along the upper face, which is about 5 to 6 feet above high-water mark. These coral fragments are derived in part from the corals living on the lagoon face of the northern shore, and in part of fragments broken by the waves from somewhat below the low-water mark. The ledge which underlies the beach crops out at many places on the lagoon side of the northern shore; we traced it also along the shores of Avatoru Pass, and about half-way across the narrow land running between Avatoru and Tiputa Passes. It crops out also at various points between them in the narrow cuts which divide this part of the northern land of the lagoon into a number of smaller islands. These secondary passes leave exposed the underlying ledge, full of fossil corals.

It became very evident, after we had examined the south shore of the lagoon, that the ledge underlying the north shore is the remnant of the bed, an old Tertiary coralliferous limestone which at one time covered the greater part of the area of the lagoon, portions of which may have been elevated to a considerable height. This limestone was gradually denuded and eroded to the level of the sea. Passages were formed on its outside edge, allowing the sea access to the inner parts of the lagoon. This began to cut away the inner portions of the elevated limestone, forming large sounds, as in the case of Fiji atolls, and leaving finally on the south side only a flat strip of perhaps 2500 to 3000 feet in width which has gradually been further eroded on the lagoon side, and also on the sea face to leave only a narrow strip of land about 1000 feet in width and perhaps 10 to 14 feet in height, the material for this land having come from the disintegration of the ledge of Tertiary limestone, both on the sea face and the lagoon side.

The underlying ledge is not the remnant of a modern reef; its character is identical with that of the elevated limestones of Fiji, which are of Tertiary age, and the rock is in every respect the same as that I observed on many of the elevated islands of Fiji. The atoll of Rairoa is in a stage of denudation and erosion very similar to that of Ngele Levu, in Fiji, only in Ngele Levu the elevated limestone attains a height of about 60 feet. Our visit to the south shore of the lagoon, both on the lagoon side and on the sea face, left us no doubt regarding the character of the underlying ledge of the north shore. As soon as the south shore was sufficiently near, as seen from the lagoon side, for us to distinguish its character, we could see that the entire shore line was formed of a high ledge of limestone, honeycombed, pitted and eroded, both by atmospheric agencies and the action of the waves, in its lower parts both on the lagoon side and on the sea face. The great rollers of the weather side broke through between the columnar masses of the ledge into the lagoon, and as far as the eye could reach there extended a more or less continuous wall.

Crossing over to the weather side of the southern land of Rairoa in one of the passages between two of the islands, we came upon the limestone ledge, from 12 to 14 feet high and about 40 to 50 feet wide, which formed the sea face of the islands and islets, and extended far to the westward as a great stone wall more or less broken into distinct parts. We found this ledge to consist of elevated limestone as hard as calcite, full of corals, honeycombed and pitted, and worn into countless spires and spurs, and needles and blocks of all sizes and shapes, separated by deep crevasses or potholes, recalling a similar scene in Ngele Levu on the windward end of the lagoon. In the passages the parts of the ledge which had not been eroded extended as wide buttresses, gradually diminishing in height till they formed a part of the lagoon flat and extended out below the recent beach rock which covered it in short stretches.

The amount of water which is forced into such a lagoon as Rairoa is something colossal, and when we observe that there are but a small number of passages through which it can find its way out again on the leeward side, it is not surprising that we should meet with such powerful currents (7 to 8 knots in several cases) sweeping out of the passages on the lee sides.

The islands and islets of Rairoa are fairly well covered with low trees and shrubs and large groves of palm trees.

It was with great interest that we approached Makatea, as it is the only high elevated island of which Dana speaks as occurring in the western Paumotus. For though he mentions some others as possibly having been elevated 5 to 6 feet, yet he considered them all, as well as Makatea (Metia or Aurora, of Dana) as modern elevated reefs. Yet, from the very description given by him of the character of the cliffs and of the surface of Makatea, I felt satisfied that it was composed of the same elevated coralliferous limestone so characteristic of the elevated reefs of Fiji, and which, from the evidence of the fossils and the character of the rock, both Mr. Dall and myself have been led to regard as of Tertiary age.

The cliffs had the same appearance as those of Vatu Leile, Ongea, Mango, Kambara, and many other elevated islands of Fiji. There were fewer fossils, perhaps, but otherwise the petrographic character of the rock was identical with that of Fiji.

The south-western extremity of the island sloped gradually to the sea, and showed two well-defined terraces. The lines of these two terraces could, as a rule, be traced along the faces of the vertical cliffs by the presence of caverns along the lines of those levels, similar to the lines of caverns indicating the line of present action of the sea at the base of the cliffs.

During our stay in Papeete some time was spent in examining that part of the barrier reef of Tahiti which had been surveyed by the *Challenger*. We found the condition of the outer slope of the reef quite different from its description as given in the *Challenger* narrative. The growing corals were comparatively few in number, and the outer slope showed nothing but a mass of dead corals and dead coral boulders beyond 16 or 17 fathoms, few living corals being observed beyond 10 to 12 fathoms.

We also made an expedition to Point Venus, to determine, if possible, the rate of growth of the corals on Dolphin Bank from the marks which had been placed on Point Venus by Wilkes, in 1839. and by MM. Le Clerk and de Bénazé, of the French navy, in 1869. We found the stones and marks as described, but on examining Dolphin Bank in the steam launch I was greatly surprised to find that there were but few corals growing on it. I could see nothing but sparsely scattered heads, none larger than my fist! the top of the bank being entirely covered by Nullipores, although we sounded across the bank in all possible directions and examined it thoroughly. It is greatly to be regretted that Dolphin Bank was not examined, neither in 1839 nor in 1869, and notes made of what species of corals, if any, were growing on its surface; for an excellent opportunity has been lost to determine the growth of corals during a period of 60 years. The choice of this bank as a standard to determine the growth of corals was unfortunate, as it is in the midst of an area comparatively free from corals.

From Papeete we steamed back to Makatea, and examined the island more in detail. We crossed the island from west to east, the path leading down from the summit of the cliffs bordering the island into a sink at least 40 to 50 feet lower than the rim of either face of the island. The sink occupies a little more than one-third the length of the island. It is deeper at its southern extremity, where it is said to be 75 to 100 feet below the rim of the adjoining cliffs.

It is difficult to determine if this sink is the remnant of the former lagoon of the island, or of a sound formed during its elevation, or if it has been formed by the action of rain and atmospheric agencies. The amount of denudation and erosion

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to which this island has been subjected is very great, as is clearly indicated by the small cañons, pinnacles, and walls of limestone, as well as by the crevasses which occur in the surface of the basin in all directions. The extent to which this action has penetrated into the mass of the island is also plainly shown by the great number of caverns which crop out at all levels along the sea face of the cliffs, some of which are of great height, and extend as long galleries into the interior of the island.

From Makatea, we visited Niau, Apataki, Tikei, Fakarava, Anaa, Tahanea, Raroia, Takume, Makemo, Tekokota, Hikuero, Marokau, Hao, Aki-Aki, Nukutavake, going as far east as Pinaki, when we turned westward again and made for the Gloucester Islands. These, as well as Hereheretue, proved most interesting; they formed, as it were, an epitome of what we had seen on a gigantic scale in the larger atolls of the western and central Paumotus. We could see at a glance in such small atolls as Nukutipipi and Anu-Anurunga the connection between structural features which, in an atoll of 40 miles in length and from 10 to 15 miles in width, it was often difficult to determine.

The deepest sounding among the Paumotus was on the line to the northward of Hereheretue in the direction of Mehetia, where we found a depth of 2524 fathoms, and a continuation of the red clay characterising the soundings since we left Pinaki.

We have seen nothing in this more extended examination of the group tending to show that there has anywhere been subsidence. On the contrary, the condition of the islands of the Paumotus cannot, it seems to me, be explained on any other theory except that in their present condition they have been formed in an area of elevation—an area of elevation extending from Matahiva on the west to Pinaki in the east, and from the Gloucester Islands on the south to Tikei on the north.

All the Paumotu Islands we have examined are, without exception, formed of Tertiary coralliferous limestone which has been elevated to a greater or less extent above the level of the sea, and then planed down by atmospheric agencies and submarine erosion, the greatest elevation being at Makatea (about 230 feet), and at Niau, where the Tertiary coralliferous limestone does not rise to a greater height than 20 feet. At Rairoa it was 15 to 16 feet high. At other islands it could be traced only as forming the shore platform.

The appearance of the old ledge and of the modern reef rock is so strikingly different that it is very simple to distinguish the two, even where only comparatively small fragments are found.

In the Paumotus, the islands have been elevated to a very moderate height, and probably to nearly the same height, for the old ledge forming the base of the modern structure is found exposed nearly everywhere at about low-water, when it cannot be traced at a slightly greater elevation. This would readily account for the nearly uniform height of the islands throughout the group.

But there is another element which comes into play in this group, and has an important part in shaping the ultimate condition of these atolls. At the Fijis we have seen the submarine erosion continue until there is little left of many of the atolls beyond the merest small islet or rock to indicate its structure. In the Paumotus, in the great atolls which are evidently only the exposed summits of parts of ridges or spurs of an extensive Tertiary coralliferous limestone bed, the rim of the atoll is, after having been denuded to the level of the sea, again built up from the material of its two faces, which is thrown up on the wide reef flats both from the sea face and from the lagoon side.

Many of the lagoons are filled with shoals or ledges awash or a few feet above the sea-level. These shoals are parts of the old ledge which have not as yet been eroded, and the disintegration of which has gone far to supply the material for the land of the outer rims of the atolls.

The lagoons of these atolls have a general depth of 13 to 20 fathoms. In some cases they are somewhat deeper, as is stated, but there are no measurements, the greater depths, 30 fathoms or more, being due to orogenic conditions. Some of the atolls are quite shallow, as at Matahiva, as well as Pinaki, where the lagoon is not more than 2 to 3 fathoms, and Takume, where it is from 5 to 6 fathoms deep. Some of the smaller islets we visited, among which are Tikei, Aki-Aki, and Nukutavake, have no lagoons.

The only atoll we have seen the lagoon of which is entirely shut off from the sea is Niau In this case the old ledge forming the rim of the land, which surrounds the nearly circular lagoon, is about a third of a mile in width and sufficiently high, 15 to 20 feet, to prevent any sea from having access to it except in case of a cyclone. It is very difficult in this case to decide whether this lagoon has been gradually filled up after elevation, or whether it is merely a sink on a more or less uneven limestone surface.

Dana and other writers on coral reefs mention a great number of lagoons as being absolutely shut off from the sea. I take it these statements are due to their descriptions being taken from charts, many of which, as in the cause of the Paumotus, are very defective. For nothing is easier than to pass at a short distance by the wide or narrow cuts which give in so many cases the freest access to the sea to the interior of the lagoons, and described as closed because they have no boat passages. I could mention, as instances of such lagoons, those of the atolls of Takume, Hikuero, Anaa, &c., which may be said to be closed, yet into which a huge volume of water is poured at every tide over low parts of the encircling reef flats.

The character of the coral reefs of the Paumotus is very different from that of other coral reef regions I have seen. Nowhere have I seen such a small number of genera, so many small species, and such stunted development of the corals. None of the great heads of the genera so characteristic of the West Indian regions, or of the Great Barrier Reef of Australia, are to be seen, with the exception of a couple of species of alcyonaria they are absent, so far as our experience shows, and there are but few sponges and gorgonians to be found among the corals.

The same paucity of animal life seemed to extend to the deep-water fauna. All the hauls we made off the islands, in from 600 to 1000 fathoms, usually the most productive area of a sea slope, brought nothing, or so little that we came to grudge the time spent in trawling on the bottom, as well as towing on the surface or near it, a great contrast to the conditions in the Atlantic in similar latitudes. and very different from our anticipations.

From Papeete we steamed to Aitutaki, Niue, and for the deep hole of the Tonga-Kermadec Deep, about 75 miles to the eastward of Tonga-Tabu, and in 4173 fathoms made a haul with the Blake beam-trawl, by far the deepest trawl haul yet made. We found in the bag a number of large fragments of a silicious sponge belonging probably to the genus Crateromorpha, which had been obtained by the *Challenger* in the Western Pacific, but in depths less than 500 fathoms. We also brought up quite a large sample of the bottom; it consisted of light brown volcanic mud mixed with radiolarians.

On our way back to Papeete from the Paumotus we examined the eastern coast of Tahiti, and from Papeete studied the western coast as far as Port Phaeton, at Tararoa Isthmus. We also examined, in a general way, the Leeward Society Islands; Murea, Huaheine, Raiatea, Tahaa, Bora-Bora, Motu Iti and Maupiti. There are excellent charts of the Society Islands, so that it was comparatively simple to examine the typical points of the group and to gain an idea of their structure so far as it relates to coral reefs. The Society Islands are all volcanic islands edged with shore platforms, some of great width, upon which the barrier or the fringing reefs of the islands have grown. The structure of the reefs of the Society Islands is very similar to that of the Fiji reefs round volcanic islands. A comparison, for instance, of the charts of Kandavu, Viti Levu, Mbengha, Nairai, and of other volcanic islands in the Fijis, with those of the Society Group, will at once show their identity. Huge platforms of submarine denudation and erosion characterise both, with fringing and barrier reefs determined by local conditions. Perhaps it is easier to follow the changes which have taken place in the Society Islands; and such islands as Tahaa and Bora-Bora, where we anchored, as well as Maupiti, are admirable examples and epitomes of the structure and mode of formation of the coral reefs of that group.

The only island of the Cook Group which we examined was Aitutaki, as Atiu is composed of elevated limestone, and Rarotonga is volcanic; I hoped we might find that atoll to be in part volcanic and in part composed of elevated coralliferous limestone; we found it to be volcanic, an island with the structure of Bora-Bora on a smaller scale.

We anchored at Niue, an island composed of elevated coralliferous limestone showing three well-marked terraces, the lowest of not more than 5 to 10 feet and in many places disappearing completely, the limestone cliffs rising vertically from the sea well into the second or even the third terraces.

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The second terrace varies in height from 50 to 60 feet, the third from 90 to 100 feet. The second terrace is deeply undercut; and in the higher vertical cliffs extending into the third terrace from the sea, the former positions of the terraces are usually indicated by lines of caverns.

From Niue we went to the Tongas, which we found a most interesting group. The elevated Tertiary coralliferous limestones take here their greatest development, and are on a scale far beyond that of their development in the Lau Group of the Fijis, or the Paumotus. The first island of the Tongas we visited, Eua, is perhaps the most interesting of the islands composed of Tertiary elevated coralliferous limestone I have visited. From Dana's account of it, evidently given at second hand, I expected to find an island somewhat like Viti Levu on a very much smaller scale. But as we steamed up to it from the east there could be no mistaking the magnificent face of nearly vertical limestone cliffs forming the whole eastern face of the island, and at points rising to over a thousand feet in height. At all projecting points lines of terraces were plainly marked: at the northern point three could be followed, and at the southern extremity five, with traces of a sixth perhaps.

Upon rounding the southern extremity of the island we could see that the island was composed of two ridges, running north, separated by a deep valley, the western ridge being much lower than the eastern, not rising to a greater height than a little over 500 feet. The western ridge is also composed of limestone, and at the headlands we could trace three terraces.

We anchored at English Roads, opposite the outlet of the drainage of the interior basin, where a small river has cut its way through a depression in the shore terrace. On landing we followed the crest of the western ridge for a few miles and could see the whole valley forming the basin of the island lying between the two ridges, at our feet. Nothing could show more clearly that such an island was not an elevated atoll, but a plateau which had been eroded and denuded for a long period of time by atmospheric and other agencies.

To the westward of the Tonga Islands is a line of volcanic islands extending nearly 200 miles, at a distance of from 15 to 20 miles parallel with the trend of the four irregularly-shaped plateaux upon which rise the Tonga Islands.

The Tonga-Tabu plateau is separated from the Namuka Group plateau by a funnel-shaped channel with a depth passing rapidly into 300 fathoms from the 100-fathom line. The Namuka plateau is rectangular; its principal island is Namuka, where we anchored.

This part of the Tongas is, like the Lau Group in Fiji, made up of islands in part volcanic and in part composed of elevated coralliferous limestone.

The Haapai plateau is triangular, with isolated islands rising on the north-western side from the deep water separating it from the Vavau plateau. On the northernmost plateau of the broad ridge of the Tonga Islands is the Vavau Group, by far the most picturesque of the Tonga Islands. Several parts of the island of Vavau, as at the entrance to the harbour of Neiafu, and at Neiafu, are finely terraced; four terraces are indicated there, and other flat-topped smaller islands show traces of two or three terraces. The northern edge of Vavau Island rises to a height of more than 500 feet, and slopes in a general way southward and inland. The southern shore is deeply indented by bays and sounds, and flanked by innumerable islands and islets, some of considerable height (150 to 250 feet) which gradually become smaller and smaller as they rise towards the southward and eastward, these islands having been formed from the denudation and erosion of the greater Vavau. They form tongues of land and sea and sounds of all shapes and sizes, showing the traces of the former land-connections of the islands and islets, and their disintegration on the eastward and southward by the action of the sea.

It is evident that in the Tonga Group, which is a very extensive area of elevation, the recent corals have played no part in the formation of the masses of land and of the plateau of the Tonga Ridge, and that here again, as in the Society Islands and the Cook Islands, both also in areas of elevation, they are a mere thin living shell or crust growing at their characteristic depths upon platforms which in the one case are volcanic, in the other calcareous, the formation of which has been independent of their growth.

After leaving Suva we steamed to Funafuti, stopping on the way at Nurakita, the southernmost of the Ellice Islands. I was, of course, greatly interested in my visit of Funafuti, where a boring had been made under the direction of a committee of the Royal Society, in charge of Prof. David, of Sydney, after the first attempt under Prof. Sollas had failed. The second boring reached a depth of more than 1100 feet. This is not the place to discuss the bearing of the work done at Funafati, as beyond the fact of the depth reached we have as yet no final statement by the committee of the interpretation put upon the detailed examination of the core obtained, and now in the hands of Prof. Judd and his assistants. In addition to the above-named islands, we also examined Nukufetau, another of the Ellice Group.

After leaving Nukufetau we encountered nothing but bad weather, which put a stop to all our work until we arrived under the lee of Arorai, the southernmost of the Gilbert Islands. On our way from Tapateuea we steamed to Apamama and Maiana, which we examined, as well as Tarawa. We next examined Maraki. Both Maraki and Taritari, the last island of the Gilberts which we examined, are remarkable for the development of an inner row of islands and sand-bars in certain parts of the lagoon parallel to the outer land-rim, a feature which also exists in many of the Marshall Islands atolls.

We spent about three weeks in exploring the Marshall Islands, taking in turn the atolls of the Ralick Chain to the north of Jaluit: Ailinglab Lab, Namu, Kwajalong and Rongelab; and then the atolls of the Ratack Chain: Likieb, Wotje and Arhno. The atolls of the Marshall Group are noted for their great size and the comparatively small area of the outer land-rims, the land-rims of some of the atolls being reduced to a few insignificant islands and islets. In none of the atolls of the Ellice, Gilbert or Marshall Islands were we able to observe the character of the underlying base which forms the foundations of the land areas of these groups. In this respect these groups are in striking contrast to the Paumotus, the Society Islands, the Cook Group, Niue, the Tongas, and the Fiji Islands, where the character of the underlying foundations of the land-rims is readily ascertained. But, on the other had, these groups give us the means of studying the mode of formation of the land-rims in a most satisfactory manner, and nowhere have we been able to study as clearly the results of the various agencies at work in shaping the endless variations produced in the islands and islets of the different atolls by the incessant handling and rehandling of the material in place, or of the fresh material added from the disintegration of the sea or lagoon faces of the outer land, or of the corals on the outer and inner slopes. It has been very interesting to trace the ever-varying conditions which have resulted in producing so many variations in the appearance and structure of the islands and islets of the land-rims of the different groups.

The boring at Funafuti will show us the character and age of the rocks underlying the mass of recent material of which the land-rim, not only of that atoll, but probably also that of the other atolls of the group and of neighbouring groups, is composed, though, of course, we can only judge by analogy of the probability of the character of the underlying base from that of the nearest islands of which it has been ascertained. When we come to a group like the Marshalls, we have as our guide only the character of the base rock of the islands of the Carolines, which is volcanic; while Naru and Ocean Islands, to the west of the Gilberts and to the south-west of the Marshalls, indicate a base of ancient Tertiary limestone.

The Marshall Islands, as well as the Ellice and Gilbert, seem to be somewhat higher than the Paumotus; but this difference is only apparent, and is due to the difference in the height of the tides, which is very small in the Paumotus, while in these groups it may be five and even six feet.

From Jaluit we visited among the Carolines, the islands and atolls of Kusaie, Pingelap, Ponapi, Andema, Losap, Namu, the Royalist Group, Truk and Namonuito, obtaining thus an excellent idea of the character of the high volcanic islands of the group from our examinations of Kusaie and of Ponapi, while the others represent the conditions of the low atolls, having probably a volcanic basis, but this was not observed at any of those we examined.

The reefs of the volcanic islands of the Carolines are similar in character to those of the Society Islands, though there are some features, such as the great width of the platforms of submarine erosion of Ponapi and of Kusaie, and the development of a border of mangrove islands at the base of the volcanic islands, which are not found in the Society Islands.

The Truk Archipelago was perhaps the most interesting of the island groups of the Carolines, and it is the only group of volcanic islands surrounded by an encircling reef that I have thus far seen in the Pacific which at first glance lends any

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support to the theory of the formation of such island-groups as Truk by subsidence. This group was not visited by either Darwin or Dana; and I can well imagine that an investigator seeing this group among the first coral reefs would readily describe the islands as the summits, nearly denuded, of a great island which had gradually sunk. But a closer examination will readily show, I think, that this group is not an exception to the general rule thus far obtaining in all the island groups of the Pacific I have visited during this trip; that we must look to submarine erosion and to a multitude of local mechanical causes for our explanation of the formation of atolls and of barrier and encircling reefs, and that, on the contrary, subsidence has played no part in bringing about existing conditions of the atolls of the South and Central Pacific.

Nowhere have we seen better exemplified than at Truk how important a part is played by the existence of a submarine platform in the growth of coral reefs. The encircling reef protects the many islands of the group against a too rapid erosion, so that they are edged by narrow fringing reefs, and nowhere do we find the wide platforms so essential to the formation of barrier reefs. The effect of the north-east trades blowing so constantly in one direction for the greater part of the year is of course very great; the disintegration and erosion of islands within its influence is incessant, and their action undoubtedly one of the essential factors in shaping the atolls of the different groups, not only according to the local positions of the individual islands, but also according to the geographical position of the groups. Thus far I do not think any observer has given sufficient weight to the importance of the action of the trades in modifying the islands within the limits of the trades, nor has any one noticed that the coral reefs are all situated practically within the limits of the trades both north and south of the equator.

The soundings made going west from Jaluit to Namonuito indicate that the various groups are, as is the case with the neighbouring groups of the Marshalls and Gilberts, isolated peaks with steep slopes rising from a depth of over 2000 fathoms. The line we ran from the northern end of Namonuito to Guam developed the eastern extension of a deep trough running south of the Ladrones. The existence of this trough had been indicated by a sounding of 4475 fathoms to the south-west of Guam made by the *Challenger*. We obtained, about 100 miles south-east of Guam, a depth of 4813 fathoms, a depth surpassed only, if I am not in error, by three soundings made by the *Penguin* in the deep trough extending from Tonga to the Kermadecs, and by three soundings made by the U.S.S. *Nero* also to the eastward of Guam.

Guam is not wholly volcanic; the northern half consists of elevated coralliferous limestone. The vertical cliffs bordering the eastern face rise from a height of 100 to 250 or 300 feet at the northern extremity, and resemble in a way similar islands in the Paumotus (Makatea), Niue, Eua, Vavau and others in the Fijis which had made their cliffs a familiar feature in our explorations. In fact, outside of Viti Levu and Vanua Levu, this is the largest island known to me where we find a combination of volcanic rocks and of elevated coralliferous limestone. The *massif* forming the southern half of the island is volcanic, and the highest ridge, rising to about 1000 feet, runs parallel to the west coast, the longest slope being toward the east.

This volcanic mass has burst through the limestone near Agaña, and the outer western extension of the coralliferous limestone exists only in the shape of a few spurs running out from the volcanic mass, the largest of which are those forming the port of San Luis d'Apra. Near the northern extremity of the island a volcanic mass, Mount Santa Rosa, has burst through the limestone and rises about 150 feet above the general level of that part of the island.

We left Guam in time to reach Rota by day, and found that this island is a mass of elevated coralliferous limestone, the highest cliffs of which reach a height of 800 feet. Perhaps in none of the elevated islands have we been able to observe the terraces of submarine elevation as well as at Rota.

It is quite probable that others of the Ladrones, like Saipan, and the islands to the south, are composed in part at least of elevated limestone, judging from the hydrographic charts and the sketches which accompany them. On many of the northern Ladrones there are active volcanoes, so that it is very possible that the volcanic outbursts which have pushed through the limestones, or have elevated parts of the islands of the group, are of comparatively recent date.

During the last part of our cruise, from Suva to Guam, the unfavorable weather greatly interfered with our deep-sea and pelagic work; in fact with the exception of the soundings made to develop as far as practicable the depths in the regions of the various coral-reef groups we visited, we abandoned all idea of carrying out the deep-sea and pelagic work planned for the district between the Gilbert and Marshall and Caroline groups. To our great disappointment hardly any marine work could be accomplished, and our investigations were limited almost entirely to the study of the coral reefs of the regions passed through.

We were everywhere received with the greatest cordiality and courtesy: by the Governor of the Paumotus, the King of Tonga, Sir George O'Brien (the High Commissioner of the Western Pacific at Suva), Mr. E. Brandeis (the Landes-Hauptmann in charge of the Marshall Islands at Jaluit), and the Governor of the Carolines, and the Japanese authorities.

The work of the expedition was divided between Drs. W. M. Woodworth, A. G. Mayer, and my son Maximilian, who accompanied me as assistants; and Mr. C. H. Townsend, Dr. Moore, and Mr. Alexander of the Fish Commission, who had also been detailed as members of the expedition.

I must also thank Capt. Moser and the officers of the *Albatross* for the untiring interest shown by them during the whole time of our expedition in the work of the ship, which was so foreign to the usual duties of a naval officer.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

MR. R. S. CLAY, late lecturer in physics at the Birkbeck Institution, has been appointed principal of the Wandsworth Technical Institute.

THE Secondary Education Bill was read a second time in the House of Lords on Monday, after a discussion in which objection was raised to the limited character of the measure, and the large powers reserved for the Board of Education. It is not proposed to carry the Bill beyond the second reading this year.

THE first response to Mr. Chamberlain's appeal for further funds for the scientific department of the Birmingham University has been received from Sir James Chance, who has given the sum of 50,000*l.*, subject to conditions to be arranged with the University Council. The endowment fund of the University now amounts to about 400,000*l.*

THE Pass List for the 1900 D.Sc. Examination of the University of London contains the following names:—Experimental Physics: Reginald Stanley Clay, Richard Smith Willows, Harold Albert Wilson. Chemistry: Thomas Slater Price. Botany: Miss Maria Dawson. Zoology: Edgar Johnson Allen, Charles William Andrews.

SOME interesting particulars with regard to chemical and technical education in the United States were given by Prof. Chandler, of New York, in his presidential address to the Society of Chemical Industry last week. The most striking feature of the American system of higher and technical education is the fact that most of the institutions have been founded and maintained by liberal gifts of money from wealthy citizens, in many cases made during the donor's lifetime, and that only a small number have been endowed or supported by the public funds. Thus in 1899 over 33 million dollars were given in this way, the largest sum being the 15 million dollars given by Mrs. Leland Stanford, together with large tracts of land, to which as yet no precise value can be attached, to complete the endowment of the Leland Stanford Junior University. There are in all 174 donors, averaging 190,000 dollars each. Schools of chemistry are now so numerous in the United States that it is almost impossible to state their exact number, but Prof. Chandler said it is more than 100. In all there are 480 universities and colleges, and 43 technical schools. In 1899 there were 9784 students pursuing professional courses in the schools of engineering, while 1487 graduated that year, receiving the degree of civil, mechanical, electrical, or mining engineer. The value to the industrial development of the United States of such an army of thoroughly-trained engineers and chemists cannot be too highly estimated.

THE operations of the Technical Instruction Committee of the Cheshire County Council are extensive and satisfactory. All the sums received under the Local Taxation (Customs and Excise) Act of 1890 have been devoted to the promotion

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